Egypt. J. Plant Breed. 8: 161-171 (2004)

HETEROSIS AND COMBINING ABILITY IN FABA BEAN FOR SOME QUANTITATIVE CHARACTERS

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ABSTRACT

The present investigation was carried out under insect free cage. A diallel crossing system excluding reciprocal involving five parents of faba bean was studied to estimate different sources of genetic variability and other parameters for seed yield and its components. Mean heterosis values relative to their respective mid and better parents were significantly positive in several crosses for all characters under studied. The highest heterosis values of F_1 based on mid parent means for date of flowering, plant height, height of first pod, number of branches, pods, seeds, seed weight/plant, seed index and number of seeds/pod were 12.81 %, 13.62 %, 20.69 %, 60.49 %, 70.82 %, 69.96 %, 71.94 %, 10.18 % and 18.88 % respectively. Furthermore the some F_1 gave more date of flowering, plant height, height of first pod, number of branches, pods, seeds, seed weight/plant, seed index and number of seeds/pod than the highest parents for same characters. The increased seed yield in F_1 hybrids seems to be due to the high manifestation of hybrid vigor in the yield components. The variances of general combining ability were smaller than those for specific combining ability for all characters studied except seed index and number of seeds/pod which suggested that the major portion of the genetic variance in the base populations was non-additive in nature. It is interesting to report that the parent which was high general combiner for pods and seeds/plant was also high combiner for seed weight/plant. The superior combinations involved one positive general combiner or one positive and other negative combiner or one negative combiner. The best three crosses of seed yield were P1x P4, P2x P3 and P2x P4.

Key words: ***Heterosis, Combining ability, Vicia faba.***

INTRODUCTION

Faba bean (*Vicia faba* L.) is an important legume crop in Egypt. It can be exploited both as subsistence and as a commercial crop in many different ways. Improvement of earliness and high yield potential are the primary objectives of faba bean breeding programs. An understanding of the fundamental nature of the actions and interactions of genes involved in the inheritance of quantitative characters is very helpful to plant breeders in their evaluation of various selection and breeding procedures. The breeding system needs to be fitted to the type of gene action to maximize the result of improvement. The diallel analysis is a method used to identify those parents (and hybrids) that have superior combinations of the characters of interest as well as to gain a better understanding of the nature of gene action involved in controlling quantitative characters. Heterosis results from the combined action and interaction of allelic and interallelic genes. The estimation of the additive and dominance components of genetic variance is very important in evaluating the potential of any heterotic response. Combining ability analysis helps the breeder to identify the best combiners which may be hybridized either to exploit heterosis or to build up the favorable fixable genes. In self-fertilized crops where commercial exploitation of heterosis is not feasible, the breeder will primarily be interested in higher magnitude of additive genetic variance for establishing superior genotypes. Several authors found the significance of both general and specific combining ability effects for important agronomic traits, yield and its components (El–Hady *et al* 1997, 1998; Abdalla *et al* 1999, 2001, El–Hosary 1983 a, b and Mansour *et al* 2001).

The main objectives of this investigation were to determine the magnitude of heterosis and understanding the nature of gene action and relative magnitude of combining ability influencing number of days to flowering and maturity as well as seed yield and major yield attributes.

MATERIALS AND METHODS

The work was conducted at Gemmiza Agricultural Research Station , ARC , Egypt during the two successive seasons of 2002 / 2003 and 2003/ 2004 under insect free cage. Five genotypes of faba bean of divers origin were used as parental lines. The common names and origin are presented in Table 1.

Table 1. Some characteristics of the five parental genotypes.

Genotype	flowering	Seed size	Pedigree
Nubaria 1 (P1)	Late	Large	Selection from Spanish Genotype (Reina Blanca)
Triple white(P2)	Early	Medium	Introduced from Sudan
Giza 3 (P3)	Early	Medium	Cross (Giza 1 X Dutch introduction 29)
Giza 716 (P4)	Early	Medium	461/842/83 X 503/ 453/ 83
Misr 2 (P5)	Early	Medium	Selection from Yousef El – Seddeek.

Diallel crosses among the parents, excluding reciprocals, were made. In the second season the five parents and their 10 possible F_1 hybrids were grown in a randomized complete block design with three replications under insect free cage. Each entry was represented by a single – row plot 3 m long with 60 cm between rows. Seeds were spaced 20 cm apart with one seed / hill. The recommended cultural practices for faba bean production were adopted throughout the growing season. At harvest, 10 competitive plants were randomly sampled from each plot to provide measurements for date of 50 % flowering, date of maturity, plant height, height of first pod, number of branches per plant, number of pods, seeds per plant, seed yield per plant, seed index, and number of seeds per pod.

The data were statistically analyzed on the mean plot bases according to Method II Model I of Griffing (1956). Heterosis was determined as the percentage increase of F_1 over the mid parents and the better parents as follows:

$$\text{Mid – parent(MP) heterosis} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

$$\text{Better parent(BP) heterosis} = \frac{\overline{F_1} - \overline{BP}}{BP} \times 100$$

RESULTS AND DISCUSSION

Significance of variance and mean performance

Mean squares of genotypes (general and specific combining ability) revealed highly significant differences among genotypes for all characters, which indicated wide variability (Table 2). The mean performance of the five parents and their 10 F_1 crosses are given in Table (3). Nubaria 1 plants beard the lowest number of pods and seeds with heaviest seed weight, 100 seed weight and intermediate height. It had high first pod and branches. However the genotype Giza 3 possessed short somewhat early flowering, maturity, the highest number of seeds and first pod, whereas the genotype Triple white exhibited lowest number of branches, number of seeds, seed weight and seed index.

Table 2. Significance of mean squares due to genotypes , general (GCA) and specific (SCA) combining ability and GCA / SCA ratio for the character measured.

Characters	Genotypes	GCA	SCA	GCA/SCA	Error
d.f	20	5	15		40
Date of 50 % flowering	67.009**	44.194**	10.203**	4.332	2.092
Date of maturity	36.451**	13.703**	12.810**	1.070	1.988
Plant height, cm	168.31*	74.441*	54.186**	1.374	18.812
Height of first pod, cm	62.190**	32.029**	18.011**	1.778	4.151
No.of branches/Plant	1.999**	0.796**	0.683**	1.165	0.131
No.of pods/ plant	150.73*	27.973	65.724*	0.426	23.151
No.of seeds/Plant	761.09**	47.502	373.53**	0.127	53.073
Seed weight/ plant, g	303.252**	73.087**	124.758**	0.586	16.777
Seed index, g	156.877**	103.669**	35.268*	2.938	11.201
No.of seeds/Pod	0.177*	0.114**	0.0408	2.794	0.0275

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 3. Mean performance of parents and F1's generation for yield and its components in faba bean.

Genotype	Date of 50 % flowering	Date of maturity	Plant height, cm	Height of first pod, cm	No.of branches/plant	No.of pods/ plant	No.of seeds/ plant	Seed weight/ plant, g	Seed index, g	No.of seeds/pod
P1 Nubaria 1	66.0	164.0	100.3	36.0	5.1	21.7	55.07	50.15	90.03	2.56
P2 T.W.	51.67	157.0	104.8	29.0	2.3	28.0	62.03	37.34	61.43	2.21
P3 Giza 3	49.67	156.3	111.0	24.7	3.1	26.9	70.23	45.56	66.1	2.62
P4 Giza 716	57.67	161.3	114.3	31.7	4.1	27.5	64.20	38.99	68.49	2.33
P5 Misr 2	52.0	160.0	109.7	33.3	3.9	36.4	62.53	45.77	73.23	1.95
P1X P2	54.33	156.0	110.5	23.3	3.4	40.3	87.07	59.02	64.95	2.19
P1XP3	51.0	153.7	98.7	22.0	3.8	32.3	85.97	62.68	72.51	2.69
P1XP4	61.33	163.7	115.8	32.4	5.4	41.7	96.67	67.91	70.04	2.32
P1XP5	56.33	161.0	108.8	29.9	4.1	49.6	99.93	64.79	64.79	2.14
P2XP3	49.67	155.7	109.3	22.4	4.3	37.4	95.0	59.19	62.3	2.55
P2XP4	61.67	160.0	106.7	25.7	5.1	40.0	105.93	65.62	62.43	2.65
P2XP5	56.0	164.0	121.8	25.8	4.5	35.2	87.17	48.77	63.91	2.48
P3XP4	58.33	164.3	125.3	28.0	4.6	31.8	75.43	55.96	74.14	2.37
P3XP5	57.0	162.3	120.3	35.0	3.7	30.7	66.93	42.67	63.97	2.18
P4Xp5	56.33	159.3	114.3	30.7	3.7	37.1	71.67	46.96	65.69	1.93
Parental mean	55.4	159.7	108.0	30.9	3.69	28.1	62.81	43.56	71.86	2.33
Overall F_1 mean	56.20	160.0	113.2	27.5	4.27	37.6	87.18	57.36	66.56	2.35
C.V.%	4.84	1.53	6.74	12.3	15.3	24.2	15.96	13.45	8.48	12.3
L.S.D. 0.05	4.189	4.084	12.56	5.90	1.05	13.9	21.10	11.86	9.69	0.48

The cross between P1xP2, P1x P3, P1xP4, P1xP5, P2xP3 and P2xP4 possessed the highest values of plant seed weight (59.02, 62.68 , 67.91 , 64.79 , 59.19 and 65.62 g respectively). Four crosses P2xP5, P3xP4 , P3xP5 and P4xP5 were early flowering (56, 58.3, 57 and 56.3 days respectively) , moderate of maturity. The cross P1xP4 gave the highest values of branches (5.4) and plant seed yield (67.91 g). Generally the mean of plant height, first pod , branches , pods , seeds and seed weight/plant for all crosses were 113.2, 27.5, 4.27, 37.6, 87.18 and 57.36 g respectively greater than the overall parental means.

Heterosis

Estimates of heterosis percentages over both mid parents and better parents are presented in Table (4). Number of days to 50% flowering showed significant deviation in seven crosses 1, 2 , 4 , 6 , 7 , 8 and 9 from mid parents varying from –11.82 % to 12.81 % but being only positive in crosses 6 , 7 , 8 and 9. However, significant positive heterosis was present in crosses 1, 3, 4, 6, 7, 8, 9 and 10 over the better parents. For number of days to maturity the cross 2 exhibited significant negative heterosis over mid parent , on the other hand two crosses 7 and 8 showed a significant positive heterosis over better parents. Similar results was obtained for these two characters by El Hosary (1983b), Abo-El- Zahab *et al* (1984), El– Lithy (1996), Mansour *et al* (2001) and Rabie (2001).

Plant height for two crosses 7 and 8 had significant positive heterosis over mid parents. For height of first pod all the crosses except cross 9 exhibited significant decrease over mid and better parents, the heterosis values over mid parent ranged from – 28.41 % to 20.69 % and ranged from –19.77 % to 41.89 % over better parents.

For number of branches crosses exhibited highly significant heterotic increases or decreases relative to mid and better parents. The values ranged from –7.32 % to 60.49 % over mid parents and ranged from – 33.12 % to 41.29 % over better parents. These results is in agreement with those obtained by Khalil (1969), Nassib (1982) , Abdalla *et al* (1999, 2001) and Attia *et al* (2002).

Heterosis for complex trait like yield is simply the consequence of multiplicative relationships at the phenotypic level between its components (Melchinger *et al* 1994). F_1 hybrids showed marked heterosis for pod and seed production as reported by Abdalla and Fischbeck (1983). Moreover, various cross-combinations exhibited different degrees of F_1 superiority in various traits based on the genes in parental combinations that may

Table 4. Expression of heterosis in F_1 over mid and better parents in percentage for studied characters.

Cross		Date of 50% flowering	Date of maturity	Plant height, cm	Height of first pod, cm	No.of branches/ plant.	No.of pods/ plant	No.of seeds/ plant	Seed weight/ plant, g	Seed index, g	No.of seeds/ pod
P1 XP2 (1)	M.P	-7.649 **	-2.80	7.702	-28.41 **	-8.036 **	62.15 **	48.71 **	34.92 **	-14.22 **	-8.04 **
	B.P	5.161 *	-0.64	5.407	-19.77 **	-33.12 **	43.81 **	40.36 **	17.69 **	-27.85 **	-14.21 **
P1XP3 (2)	M.P	-11.82 **	-4.06 *	-6.625	-27.47 **	-7.317 **	33.10 **	37.22 **	30.97 **	-7.11	4.12 **
	B.P	2.685	-1.706	-11.11	-10.81 **	-25.97 **	20.22 **	22.40 *	24.98 **	-19.45 **	2.93 **
P1XP4 (3)	M.P	-0.809	0.62	7.919	-4.335	17.39 **	69.88 **	62.10 **	52.36 **	-11.64 **	-4.85 **
	B.P	6.358 **	1.45	1.312	2.211	5.196 **	51.94 **	50.57 **	35.41 **	-22.21 **	-9.13 **
P1XP5 (4)	M.P	-4.520 *	-0.62	3.587	-13.65 **	-8.148 **	70.82 **	69.96 **	35.09 **	-20.62 **	-4.95 **
	B.P	8.333 **	0.63	-0.821	-10.20 **	-19.48 **	36.30 **	59.81 **	29.19 **	-28.03 **	-16.17 **
P2XP3 (5)	M.P	-1.974	-0.64	1.328	-16.52 **	60.49 **	36.33 **	43.65 **	42.81 **	-0.89	5.59 **
	B.P	0.00	-0.426	-1.502	-9.19 **	41.29 **	33.57 **	35.26 **	29.92 **	-4.34	-2.55 **
P2XP4 (6)	M.P	12.81 **	0.52	-2.647	-15.28 **	59.38 **	44.23 **	67.84 **	71.94 **	-3.90	16.59 **
	B.P	19.36 **	1.91	-6.705	-11.38 **	25.41 **	42.86 **	65.01 **	68.30 **	-8.85	13.75 **
P2XP5 (7)	M.P	8.039 **	3.47	13.62 *	-17.11 **	45.70 **	9.37	39.95 **	17.37 **	-5.08	18.88 **
	B.P	8.387 **	4.46 *	-0.763	-10.92 **	16.81 **	-3.21	39.39 **	6.55	-12.72 *	11.90 **
P3XP4 (8)	M.P	8.696 **	3.46	11.24 *	-0.59	28.97 **	17.18 **	12.22	32.37 **	10.18 *	-3.98 **
	B.P	17.45 **	5.117 *	9.621	13.51 **	13.12 **	15.90 *	7.40	22.83 **	8.25	-9.30 **
P3XP5 (9)	M.P	12.13 **	2.63	9.063	20.69 **	7.69 **	-3.01	0.83	-6.56	-8.17	-4.45 **
	B.P	14.77 **	3.84	8.408	41.89 **	-3.45 **	-15.68 *	-4.70	-6.77	-12.64 *	-16.56 **
P4XP5 (10)	M.P	2.74	-0.83	2.083	-5.64 *	-7.56 **	16.35 **	13.10	10.80 *	-7.29	-9.81 **
	B.P	8.33 **	-0.42	0.00	-3.16	2.46 **	2.11	11.63	2.59	-10.29 *	-17.05 **
Overall Mean	M.P	1.764	0.849	4.727	-10.89	6.758	38.64	39.558	32.207	-6.874	0.91
	B.P	9.038	0.962	0.385	-1.792	2.227	22.78	32.713	23.069	-13.813	-5.639

* ,** Significant at 0.05 and 0.01 levels of probability, respectively.

contribute directly or indirectly to characteristics Attia (1998). Different values of heterosis might be due to the genetic diversity of the parents with non-allelic interactions, which increase or decrease the expression of heterosis (Hayman 1957). Even in the absence of epistasis, multiple alleles at a locus could lead to either positive or negative heterosis (Cress 1966).

Highly significant average heterotic effects expressed as percent increase the F_1 hybrids over the average of the parents were found for number of pods (70.82 %), seeds (69.96 %) and seed weight (71.94 %). Useful heterosis over high parents was also exhibited for number of pods (51.49 %), seeds (65.01 %) and seed weight (68.30 %). For seed index four crosses exhibited significant heterosis over mid parents ranged from –20.62 % to 10.18 % and seven crosses over high parents ranged from –28.03 % to – 10.29 %. For number of seeds / pod some crosses exhibited highly significant heterosis over mid parents ranged from –3.98 % to 18.88 % and high parents ranged from –17.05 % to 13.75 %. These results is in agreement with those obtained by El – Hosary (1981), El – Hosary (1983a), Bakheit (1992), Abo– El–Zahab *et al* (1994) and El – Hady *et al* (1997).

Combining ability

The significance of variances for both general (GCA) and specific (SCA) combining ability and GCA/SCA ratio are presented in Table (2). Mean squares of both estimates were highly significant (or significant) for the studied traits except of GCA for number of pods and seeds/plant and SCA for number of seeds/pod. The ratio of both estimates exceeded the unity for flowering, maturity, plant height, first pod, branches, seed index and seeds/pod. This indicated that most of the genetic variation among the investigated genotypes for the mentioned traits appeared to be additive. Thus, selection could be favored for improving these traits. However, low GCA/SCA ratio (less than unity) for particularly number of pods, seeds and seed weight/plant revealed the predominance of non-additive gene action in these traits. Similar results were obtained by Khalil (1969), Mahmoud (1977) Nassib (1982), Abo El-Zahab *et al* (1994 a &b), Helal (1997), El–Hady *et al* (1998), Rabie (2001) and Attia *et al* (2002).

General combining ability estimates of the five parents for the previous mentioned characters are given in Table (5). Concerning date of flowering the parents 1 and 4 proved to be good combiners for flowering date and had positive GCA effect. On the other hand three parents P2, P3 and P5 showed negative response of GCA effect for this character. For maturity date two parent revealed a negative GCA effect (P2 and P3), but the parent 4 proved a good combiner for giving maturity date. The parent P1

Table 5. Estimates of general combining ability effects (gi) of the parental genotypes in F_1's generation for seed yield and its components.

Parents	Date of 50% flowering	Date of maturity	Plant height, cm	Height of first pod, cm	No.of branches/ plant	No.of pods/ plant	No.of seeds/ plant	Seed weight/ plant, g	Seed index, g	No.of seeds/ pod
P1	2.77 **	0.41	-4.90 *	1.09	0.37 *	0.09	0.78	5.45 **	6.06 **	0.06
P2	-1.51 **	-1.4 *	-1.54	-2.39 **	-0.35 *	0.33	3.56	-1.33	-4.66 **	0.03
P3	-2.90 **	-1.54 *	0.10	-2.17 *	-0.27	-2.95	-1.51	-0.71	-0.56	0.14 *
P4	2.49 **	1.51 *	3.17	1.16	0.35 *	-0.14	0.54	-0.30	-0.10	-0.02
P5	-0.85	1.03	2.27	2.31 *	-0.10	2.67	-3.37	-3.12	-0.74	-0.21 **
Se gi	0.60	0.58	1.80	0.84	0.15	1.99	3.02	1.70	1.39	0.07
SE gi-gi	0.77	0.75	2.32	1.09	0.19	2.57	3.89	2.19	1.79	0.09

*,** Significant at 0.05 and 0.01 levels of probability, respectively.

Table 6. Estimates of specific combining ability effects (Sij) of the parental genotypes in F_1's generation for seed yield and its components.

Crosses	Date of 50% flowering	Date of maturity	Plant height, cm	Height of first pod, cm	No.of branches/ plant	No.of pods/ plant	No.of seeds/ plant	Seed weight/ plant, g	Seed index, g	No.of seeds/ pod
P1 X P2	-2.86 *	-2.92 *	5.46	-4.09 *	-0.67 *	5.42	3.68	2.14	-4.77	-0.24
P1 X P3	-4.81 **	-5.11**	-8.88 *	-5.57 **	-0.38	0.73	7.64	5.17	-1.31	0.15
P1 X P4	0.14	1.84	6.12	1.46	0.61	7.35	16.30 *	10.01 **	-4.25	-0.06
P1 X P5	-1.52	-0.35	-0.06	-2.12	-0.21	12.38 **	23.47 **	9.70 *	-8.85 **	-0.06
P2 X P3	-1.86	-1.30	-1.57	-1.69	0.87 **	5.59	13.89 *	8.46 *	0.09	0.04
P2 X P4	4.76 **	-0.02	-6.41	-1.73	1.02 **	5.38	22.78 **	14.49 **	-1.14	0.29
P2 X P5	2.43	4.46**	9.65 *	-2.74	0.88 **	-2.23	7.92	0.45	0.98	0.30 *
P3 X P4	2.81 *	4.46**	9.72 *	0.35	0.44	0.49	-2.66	4.21	6.48 *	-0.09
P3 X P5	4.81 **	2.94*	5.61	6.21 **	0.021	-3.49	-7.25	-6.27	-3.06	-0.10
P4 X P5	-1.24	-3.11*	-2.55	-1.46	-0.66	0.17	-4.46	-2.38	-1.80	-0.19
S.E Sij	1.26	1.23	3.79	1.78	0.32	4.20	6.36	3.58	2.92	0.15
S.E Sij-Skl	1.73	1.69	5.18	2.44	0.43	5.75	8.71	4.90	4.00	0.20

*,** Significant at 0.05 and 0.01 levels of probability, respectively.

showed consistent positive GCA effects for number of branches, seed weight/plant and seed index. Thus this stock proved the best potential stock for improving studied traits except number of seeds/pod. However P3 could be considered as source for improving number of seeds/pod.

Specific combining ability

Out of 10 crosses, three crosses (P2xP4, P3xP4 and P3xP5) exhibited significant positive SCA effects for date of flowering, and three crosses (P2xP5, P3xP4 and P3xP5) exhibited significant positive SCA effects for date of maturity (Table 6). Two crosses (P2xP5 and P3xP4) showed significant positive SCA effects for plant height and one cross (P3xP5) for height of first pod. With respect number of branches/plant three crosses (P2xP3, P2xP4 and P2xP5) showed significant positive SCA effects. Only one cross (P1xP5) exhibited significant positive SCA effects for pods , seeds and seed yield/plant. Three crosses (P1xP4, P2xP3 and P2xP4) showed significant positive SCA effects for number of seeds and seed weight/plant. Thus SCA for seed yield seemed to be influenced by SCA for yield components. It is evident from the results that only some components of yield are more important for yield expression. In the selection program, however, adjustments as to the desired levels of each component may have to be made in order to obtain the maximum seed yield. This appears logic, because the components may compete for metabolic substrates produced by the plant and conditions which favour the development of one component could have an adverse effect on other components (Abo El – Zahab *et al* 1994, Abdalla *et al* 1999, 2001, Attia 1998 and Attia *et al* 2002). Only one cross (P3xP4) and one cross (P2xP5) showed significant positive SCA effects for seed index and number of seeds/pod respectively.

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قوة الهجين والقدرة علي التآلف في الفول البلدي لبعض الصفات الكمية

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أجريت هذه الدراسة بمحطة البحوث الزراعية بالجميزة – غربية خلال موسمي ٢٠٠٢/٢٠٠٣ ، ٢٠٠٣/٢٠٠٤ تحت الصوبة المانعة للحشرات بهدف دراسة القدرة علي التآلف وقوة الهجين للمحصول ومكوناته في خمسة تراكيب وراثية من الفول البلدي (نوبارية ١، جيزة ٣، جيزة ٧١٦، مصر ٢، Triple white) تم تهجينها للحصول على ١٠ هجن دون الهجن العكسية واوضحت النتائج ما يلى:

١– وجود فروق معنوية لقوة الهجين مقارنة بمتوسط وأعلي الأبوين فى بعض الهجن لمعظم الصفات تحت الدراسة حيث أظهرت صفات التزهير وارتفاع أول قرن علي النبات وعدد الفروع وعدد القرون والبذور ووزن البذور ووزن ١٠٠ بذرة وعدد بذور القرن أعلي قوة هجين.

٢– تراوحت اعلى القيم التي تم الحصول عليها لقوة الهجين مقارنة بمتوسط الأبوين لصفات عدد الفروع ٦٠,٤٩ %، عدد القرون ٧٠,٨٢ %، عدد البذور ٦٩,٩٦ %، وزن بذور النبات ٧١,٩٤ % .

٣– أعطي الهجين رقم ٦ أعلي قوة هجين لصفات طول النبات وعدد الفروع والمحصول ومكوناته.

٤– أوضحت النتائج أن تباين القدرة العامة علي الائتلاف كان أقل من القدرة الخاصة علي الائتلاف لصفات المحصول وهذا يوضح بأن الجزء الأكبر من التباين الوراثي للعشيرة الأساسية كان غير متراكم.

٥– اتضح أن الأب ذو القدرة العامة العالية علي التآلف كان أيضا ذو قدرة خاصة عالية لصفات عدد القرون وعدد البذور ووزن بذور النبات .

المجلة المصرية لتربية النبات ٨: ١٦١-١٧١ (٢٠٠٤)